SOIL MANAGEMENT WITH COVER CROPS IN IRRIGATED VINEYARDS: EFFECTS IN VINE MICROCLIMATE (CV. MALBEC) GROWN IN A TERROIR OF AGRELO (LUJÁN DE CUYO)

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Key words: grapevine, Malbec, soil management, cover crops, microclimate, radiation, reflected radiation, temperature, relative humidity, vigour, yield, grape, wine.

Abstract

The objective of this work was to study the influence of cover crops soil management in vine microclimate. For this aim, a research was conduced to compare five different species with diverse vegetative cycle against no tillage soil management through herbicides applications. The study was developed in a vineyard of cv. Malbec trellised in vertically positioned shoots (VPS) and located in a terroir of Agrelo, Luján de Cuyo, Mendoza, Argentine. Primarily, measures of microclimatic parameters were taken: temperature, relative humidity and radiation at bunches level; soil temperature (depth: 15 cm), quantity and quality of cover reflected radiation. We verified a significant diminution of cover crop reflected PAR and a significantly poorer Red/Far red ratio than bare soil (no cultivation). Those had no effects inside the canopy, because permanent cover crops of red clover (*Trifolium pratensis*) and tall wheatgrass (*Agropyron elongatum*) resulted in a restriction in vine vigour that translated in a greater direct PAR reception at bunches level. There were not a significant variation of: maximum and minimum temperatures and temperature amplitude, at bunches level. It was remarkable that the treatments with greater ground cover had a tendency to lightly reduce the minimum temperature (-0,5 ºC for red clover and tall wheatgrass), which could be important for critical periods. Relative humidity in the canopy was not significantly affected. Red clover, tall wheatgrass, cereal rye-chess mix (*Secale cereale-Bromus catharticus*) and sudangrass (*Sorghum sudanensis*) notably decreased soil thermic amplitude. This effect was mainly due to a decrease in the maximum temperature. Cover crops species with difficulty to develop during their cycle had an intermediate behaviour or very similar to bare soil. The introduction of a permanent cover crop with a good invasion of inter row spacing modified microclimatic characteristics principally related to soil temperature and reception of radiation. It would be convenient to verify if the mentioned effects show a different intensity in a larger cover crop surface, modifying the vineyard mesoclimate.

Résumé

L'objectif de cette recherche a été de déterminer les effets de l'enherbement dans le microclimat de la vigne. On a comparé cinq couvertures de cycle végétatif différent en ce qui concerne l'entretien du sol sans culture par application d'herbicides. L'étude a été developpée dans un vignoble cv. Malbec conduit en haute espalier, situé en a terroir á Agrelo, Luján de Cuyo, Mendoza, Argentine. On a déterminé des paramètres micro climatiques: température, humidité relative et éclairement au niveau des grappes; température du sol (prof.: 15 cm), quantité et qualité du rayonnement réfléchie par l'enherbement. On constate une réduction significative de la PAR réfléchie par l'enherbement et un rapport Rouge/Rouge loin significativement inférieure à celui du sol découvert (sans culture). Ce ne fait pas une effet dans la végétation, parce que l'enherbement permanent de trèfle rouge (*Trifolium pratensis*) et agropyro élevé (*Agropyron elongatum*) déterminent une restriction de la vigueur de la vigne que se traduit en une meilleure réception directe de la radiation photosynthétiquement active (RPA) au niveau des grappes. Il n'y a pas une modification significative par rapport aux températures maximale et minimale et en l'amplitude thermique au niveau des grappes. Il faut consigner que les traitements qui présentent une grande couverture du sol montrent une tendance de réduire la température minimale (–0,5 ºC pour le trèfle rouge et agropyro élevé), que peut être important dans certains périodes critiques. L'humidité relative dans la zone des grappes n'est pas significativement affectée. Trèfle rouge, agropyro élevé, seigle-brome (*Secale cereale-Bromus catharticus*) et millet de Sudán (*Sorghum sudanensis*) présentent une considérable diminution de l'amplitude thermique du sol, déterminée principalement par une diminution de la température maximale. Les espèces qu'ont certaines difficultés de développement pendant leur cycle se comportent de manière intermédiaire ou similaire à un sol sans couverture. L'introduction d'enherbement permanent avec une bonne occupation de l'inter rang modifie les caractéristiques micro climatiques, notamment par rapport à la température du sol et à la réception du rayonnement. Il conviendra de vérifier si les effets mentionnés se manifestent avec une intensité différente selon l'importance de la surface enherbée, modifiant ainsi le mesoclimat du vignoble.

Introduction

The largest part of regional vineyard soils are poor structured and with a low content of organic matter (Hudson et al., 1990); cultivation of our areas through excessive tillage systems and a high transit of equipments, limited natural resource production, perceptibly affecting soil fertility, exposing it to erosion, increasing compaction problems and rising operative costs (Del Monte et al., 1994).
With herbicide introduction, no tilling of regional vineyard generalized thought the chemical control of weeds. The continuity of this practice considerably affected soil structure, determining difficulties for crop management, specially after rainfall who affect machinery traction and workers transit in general. At this conditions, it is very risky to delay cultural practices who ensure the production and his quality level, like: phyto-sanitary treatments, canopy and soil management, and grape harvest. Furthermore, there are a world tendency to reduce agro chemical use to minimize ambient contamination problems. In the last years, this problem acquire a greater importance due the large interest for crop sustainable practices, like organic or integrated vineyard management.
This situation approach the needs of alternative soil management strategies. Cover crops soil management consist in install (established cover crops) or let to develop (native cover crops) permanent or temporary vegetal species, upon the total or only a part of vineyard surface (Groupe Columa Vigne de l'ANPP, 2004), offering to grape growers important advantages related with quality and quantity, operative costs and sustainability of grape production.
Vineyard soil management has and indirect influence over canopy microclimate, through his effect in vigour and foliage characteristics changes (Smart, 1985). It is indubitable that to determinate soil management system correspond a more or less marked microclimate, that's why vegetal cover introduction determine a new active element inside the system (Calame, 1993).
Microclimate of air part is one of the basic elements, if not the principal element, of grape growing performance (Carbonneau et al., 1982).
The presence of a plant cover behaves physically like thermal insulating. On the other hand, it is an active part inside the balance of energy system, since he transpire. He needs from the solar power and competes with the energy destined for the soil surface heating (Calame, 1993).
As one begins to spread cover crops soil managing practice in our wine-growing area, there arises the need to qualify and quantify his effect in plant microclimate, his possible phyto-sanitary implications, the influence on grapes quality and his enological potential.
The principal aim of the present work is to determine, for agroclimatic conditions of our region, the influence that exercises a cover crop on vineyard microclimate, principally regarding in radiation at bunches level, temperature (in canopy and soil) and relative humidity.

Materials and Methods

The essay behaves in a vineyard located in the zone of Agrelo, Luján de Cuyo. Lat: 33 º 05 ' S; Long: 68 º 53 ' O of G. Altitude: 959 meters above mean sea level. Agro-climatic district "Represa Las Vizcacheras". Average annual rainfall of 191 mm, grapevine culture needs necessarily of the irrigation.

The water resource comes from Mendoza River by means of flood irrigation without earring.

The soil is alluvial, with texture from frank sandy to frank slimy, pH of 7,8 and CEA of 1 dS/m, with more than 2 m of depth.

Vines, consisting in a masal selection of own-rooted cv. Malbec, were planted in 1991 at 1,50 m in the row, with rows 2,70 m apart oriented north-south, vertically positioned shoots (VPS) with 1,80 m of height and spur pruned with 20 to 23 buds per vine by means of bilateral cordon.

Experimentation Variables and Statistical Design:

Treatments were six (Table 1): four different species of cover crops, a mixture of two species and integral herbicide application managing.

The essay design was randomised complete blocks with six treatments and four replications. Experimental plot of 2,7 m x 120 m with borders wings of equal surface. Every treatment occupied three inter rows, and the experimental units placed in the central inter row and in both central rows. Results were submitted to analysis of variance (ANOVA) and comparison of averages by means of significance test (LSD, 95 % of confidence), realized across the statistical package Statgraphics 4.0.

Cover crop sowed area included 67 % of total vineyard surface (width of sowing: 1,8 m). The zone under the row (90 cm of width) of all treatments was maintain free of vegetation by herbicide application. Before locating the essay, the vineyard was behaving by means of a mixing of cereal rye (*Secale cereale*) and chess (*Bromus catharticus*); this vegetable cover was adopted as an experiment treatment that supported the above mentioned original flora. The areas corresponding to the rest of the experimental plots were treated with herbicide and sowed by means of a direct sowing equipment. Different treatments soil managing detail in the Table 1; the experimental treatments began in autumn of 2001, across the sowing of triticale (*X Triticosecale*) and red clover (*Trifolium pratensis*). In the spring of 2002, sudangrass (*Sorghum sudanensis*) was established and tall wheatgrass (*Agropyron elongatum*) was sowed in the autumn of 2002. Annually, there were realized the direct re-sowing of annual species. Temporary cover treatments (sudangrass and triticale), were kept free of undergrowths during the period of rest, using two applications of herbicide during the season. The control was managed with three applications in the cycle. Systemic herbicide not selectively was used in all cases (glifosato, 6 l/ha). The coverages were kept by means of regular cuttings, in agreement to the needs of a suitable culture managing.

Principal determinations*

Canopy temperature and humidity: by data logger sensors “HOBO” model “H08-004-02”, located at bunches level and protected of direct radiation with a plastic cover. A sensor were placed by treatment and with replications in different days. Data were registered every 30 minutes for 24 hours.

Superficial temperature of berries and leaves: by means of infrared thermometer “La Crosse Technology” model “IR-101”. Determinations were realized between 16 and 17 hs, on 20 berries and 20 leaves, not directly exposed.

Soil temperature: across external sensor of temperature for datalogger “HOBO®” model “H8 TMC6-HA”. Placed to 15 cm of depth, and to 53 cm apart the row, locating a sensor for treatment and with replications in different days. Data were registered every 30 minutes for 24 hours.

Photosynthetically active radiation (P.A.R.): through a line quantum sensor “LI-COR” model “LI-191 SA”. Measurements were realized inside the canopy and at bunches level, in three moments of the day; at 10, 13 and 16 hs in two positions: with the sensor orientated towards the zenith and with the sensor orientated towards east inter row centre, of selected row.

Spectral distribution of coverage reflected radiation: using an spectroradiometer “LI-COR” model “1800”. Measurements were realized at bunches level and out of the canopy, between 11 and 13 hs with a sensor orientated towards east inter row centre, of selected row.

*Note: microclimatic determinations were realized during sunny days.

Results and Discussion

We present the results corresponding to the cycle 2003/04. To facilitate the interpretation of the results, there are exposed the microclimatic determinations realized during the ripeness stage, for being this phenological stage one in which the microclimatic parameters fulfil an essential role in the final quality of grapes.

It turns out important to clarify that the treatments of sudangrass (S) and triticale (TC) presented establishment problems due to frosts and sowing difficulties respectively, by what the effect of treatment, in these cases, was limited (we do not present the corresponding evaluations).

Photosynthetically active radiation (PAR) received at bunches level.

Permanent cover of red clover (TR) and tall wheatgrass (A) determined a greater reception of direct PAR at bunches level. There was not a significant differences respecting to reflected PAR by treatments. Total PAR received at bunches level was significantly greater in the TR and A treatments. Cereal rye-chess mix (CC) exhibited near values, but that did not reach statistically to being different. If it is taken into single account the received direct PAR in TR, A and CC, it was observed that the values surpassed the total of direct and reflected PAR in control (TE), TC and S. Treatments of TE, TC and S almost received the same amount of originating energy of direct PAR that of reflected (Figure 1). These results agree with observed in other works (Morlat et al., 1993; Barbeau et al., 1999b; Maigre, 1999 and 2000). This greater reception of radiation noticed in cover crops treatments, is related to a diminution in the vegetative growth of grapevine (data no presented). Measurement of illumination in the interior of the foliage turned out to be a good indicator of canopy porosity. In Figure 2 it is observed that permanent cover crops treatments (TR, A and CC) were distinguished to the rest (TE, TC and S) by the greater received direct PAR at the three moments of measurement; at 10 hs the levels of A and TR were significantly greater compared with TE, TC and S; at 16 hs TR and A displayed statistical differences respect TE and S. At 13 hs PAR levels descended because the sun was located at the zenith and most of light was caught by the foliage. Differences in reflected PAR were less marked than the ones observed for direct PAR, detecting statistical significance at 16 hs (Figure 3). Bunches received greater levels of reflected PAR by inter row at 10 hs, which was explained by the fact that summer trimming was made by means of a passage through east sector of the row (habitual practice in the vineyard). The operation seems to improved the reception of radiation during the morning.

Quality and quantity of inter row reflected radiation.

A significant diminution of reflected radiation in UV and Visible spectrum ranks was verified in TR, A, CC and S. TC determined a significantly greater values of reflection for the same spectrum rank, since at the time of determination it was like mulching, the greater reflection corresponded to TE. In near infra-red spectrum rank, the TC stood out of the rest by their smaller levels of reflected energy. As far as the reflected total radiation, TE was statistically different of the rest, which were not different to each other (Table 2).

In the spectral distribution of reflected radiation we could distinguish, in TR, A, CC and S treatments, the chlorophyll absorption bands between 400 and 500 nm and between 600 and 700 nm (Figure 5). In these treatments a top of reflection around the 550 nm (green) was noticed, therefore the vegetation visualizes like of green colour. After the 700 nm (near infra-red), cover crops with vegetative activity, showed a remarkable increase of the reflected energy surpassing in many cases the values of TE. In this rank TC showed the lowest values, probably due to the absorption caused by compounds related to dry vegetal material (cellulous, lignin and nitrogen). Cover crops of A, TR, CC and S (condition: green) had a “Red/Far red” ratio, for reflected radiation, significantly smaller than corresponding to TE (condition: light brown) and TC in stubble (condition: light yellow), that were not different as well statistically, exhibiting values next to the one of direct radiation for that ratio (Table 3). This indicates that covers (green) reflected light is of smaller quality, since this relation influence directly the activity of phytochrome system, photo-receptor associated to the increase in anthocyanins and sugar levels in berry (Smart et al. 1988). In any case this effect doesn’t had an adverse consequences in the grapevine, because the treatments with vegetal cover received a greater amount of direct radiation at bunches level (Figures 1 and 2).

Temperature and relative humidity at bunches level

At bunches level, a significant modification did not take place as far as: maximum and minimum temperature, and temperature amplitude (non presented data). Treatments that displayed greater ground cover, determined an slight diminution in minimum temperature respecting to discovered soil

(-0,5 ºC for TR and A), agreeing with the study of Porter (1998), that emphasized that the green covers contribute to a greater susceptibility of vineyard to spring frosts at cordon level, this effect in addition, could generate modifications in grape and wine composition. Maximum temperature, however, was slightly superior to the control (up to +0,7 ºC for A and CC). Consequently, thermic amplitude of TR, A and CC were superior (+1ºC) in relation to the remaining treatments. When considering daily thermal evolution, it was observed that TE determined the smaller registries (4,5 ºC less than TR at 10:30 hs); to the inverse one during the night, although the curves came near, to that treatment corresponded the greater thermal intensities (Figure 6).
Canopy relative humidity was not significantly affected by cover crops (non presented data). In Figure 7 it was observed that during the day levels were very close between the treatments, whereas at night (elevated relative humidity) TE determined the lowest values (4,7 % less than TR at 2:00 hs).
The analysed microclimatic effects, were a consequence due mainly to the increase in foliage porosity, shown in the determinations of radiation within canopy (Figures 1, 2 and 3).

Soil temperature

Cover crops of TR, A, CC and S significantly reduced soil thermic amplitude, in comparison with TE, who was not different from the surface covered by TC stubble; this effect was determined mainly by a reduction in the maximum temperature (Table 4). This effect agreed with indicated by Pradel and Pieri in 2000. In Figure 8 the evolution of soil temperature was appreciated during the day, the greater difference between treatments was observed during afternoon (at 16:30 hs, TE show 2,7 ºC more than TR), and the minor around mid-morning.
The stubble produced by TC turned out not to be sufficient such us determining a decrease in thermic amplitude, which was detected in other experiences with the artificial application of stubble mulching (Ludvigsen, 1995).

Conclusions

The introduction of a permanent vegetal cover of red clover, tall wheatgrass and a cereal rye-chess mix, with good vineyard inter-row invasion, modified canopy microclimatic characteristics. Mainly by a greater reception of radiation at bunches level, due to the incidence in vegetative development. Perennial green covers diminished the amount and quality of reflected light, in relation to a bare soil. This effect was not of significance within canopy, since predominated the depressive effect on the vegetative expression. Cover crops significantly reduced soil thermic amplitude at the inter-row. Thermal microclimate within canopy did not show statistical differences, although a slight diminution in the minimum temperature and slight increase of the maximum temperature was perceived, which generates a tenuous increase of thermic amplitude. This effect will have to be considered when evaluating the risk of frost in the vineyard.
Canopy relative humidity during the night showed slightly superior values to those of a vineyard with a bare soil, not significant differences were detected. Vegetal species with a low degree of ground cover, behave of intermediate way or similar to a ground without cover, since its effect was partial and it did not reach to modify significantly the vegetative growth and, like a consequence, either the microclimatic conditions at bunches level.
Probably the cover crops effects will be different in vineyards equipped with localized irrigation systems. In addition, it will be interesting to verify if detected microclimatic effects are pronounced with different intensity in greater culture surfaces, being modified vineyard mesoclimate.

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Tables and figures

Table 1. Description of experimental variables.

Treatment	Scientific name	Cycle	Code	Identification colour
Sudangrass	*Sorghum sudanensis*	Summer annual	S	
Tall wheatgrass	*Agropyron elongatum*	Perennial	A	
Red clover	*Trifolium pratensis*	Perennial	TR	
Triticale	*X Triticosecale*	Winter annual	TC	
Cereal rye-Chess	*Secale cereale-Bromus catharticus*	Winter annual Winter tri-annual	CC	
Control (herbicide)			TE	

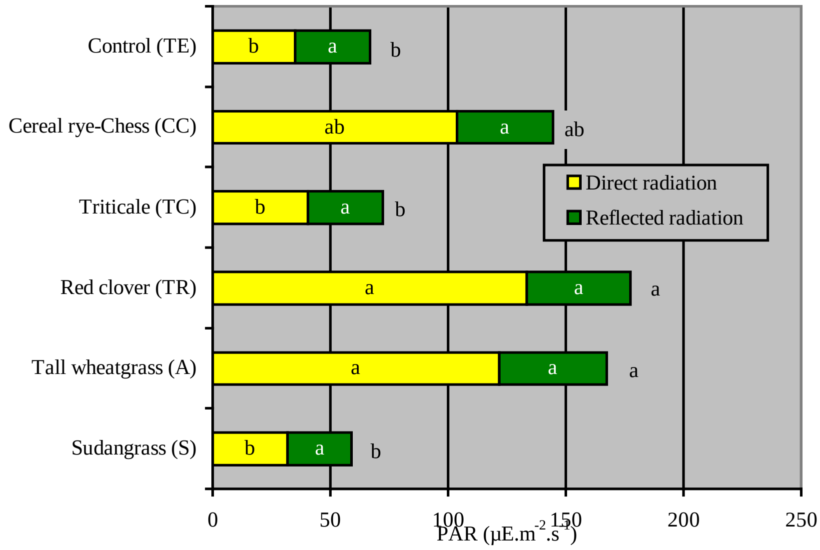

Figure 1. Direct and reflected radiation (PAR) received at bunches level during maturation (05/03/04). Means of three measurements during the day (10, 13 y 16 hs.). Same letters inside the bars of same colour indicate that there are not significant differences between means (p=0,05 by LSD test). Letter to the end of each bar compare totals.

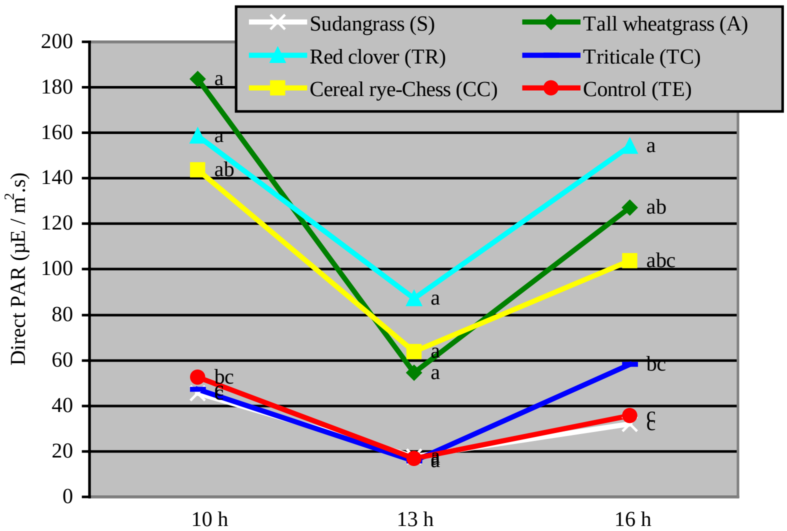

Figure 2. Direct Radiation (PAR) received at bunches level during maturation (05/03/04). Daily evolution. Same letters indicate that there are not significant differences between means (p=0,05 by LSD test).

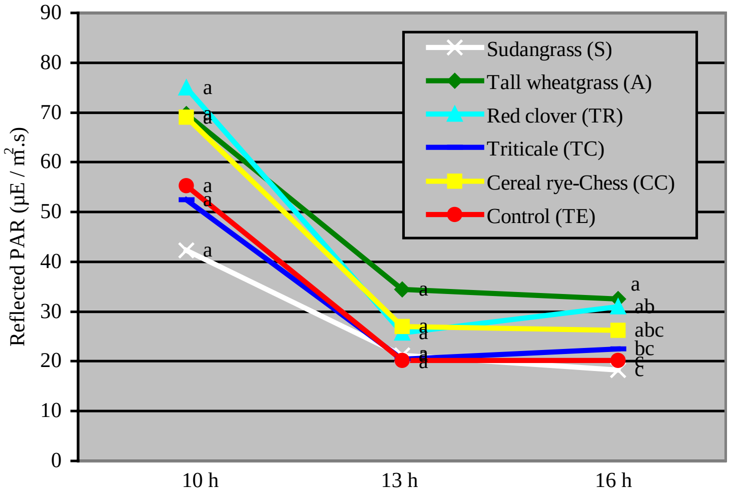

Figure 3. Reflected radiation (PAR) received at bunches level during maturation (05/03/04). Daily evolution. Same letters indicate that there not significant differences between means (p=0,05 by LSD test).

Table 2. Reflected radiation for each spectrum rank, captured out of the canopy, 01/03/04 between 11 and 13 hs. Same letters indicate that there are not significant differences between means (p=0,05 by LSD test).

	Reflected radiation (Watt/m^2.nm)						
	UV (315-400 nm)	**Blue (405-500 nm)**	**Green (505-600 nm)**	**Red (605-700 nm)**	**Near IR (705-1100 nm)**	**PAR (400-700 nm)**	**Total (315-1100 nm)**
Sudangrass (S)	0,15 c	0,55 c	0,95 bc	0,83 c	4,20 a	2,33 c	6,69 b
Tall wheatgrass (A)	0,09 c	0,48 c	0,64 c	0,40 d	4,78 a	1,51 c	6,38 b
Red clover (TR)	0,10 c	0,39 c	0,66 c	0,45 d	4,86 a	1,51 c	6,48 b
Triticale (TC)	0,29 b	0,98 b	1,26 b	1,31 b	3,36 b	3,55 b	7,20 b
Cereal rye-Chess (CC)	0,11 c	0,42 c	0,76 c	0,52 cd	4,57 a	1,71 c	6,39 b
Control (TE)	0,63 a	1,81 a	2,13 a	2,12 a	4,51 a	6,06 a	11,20 a

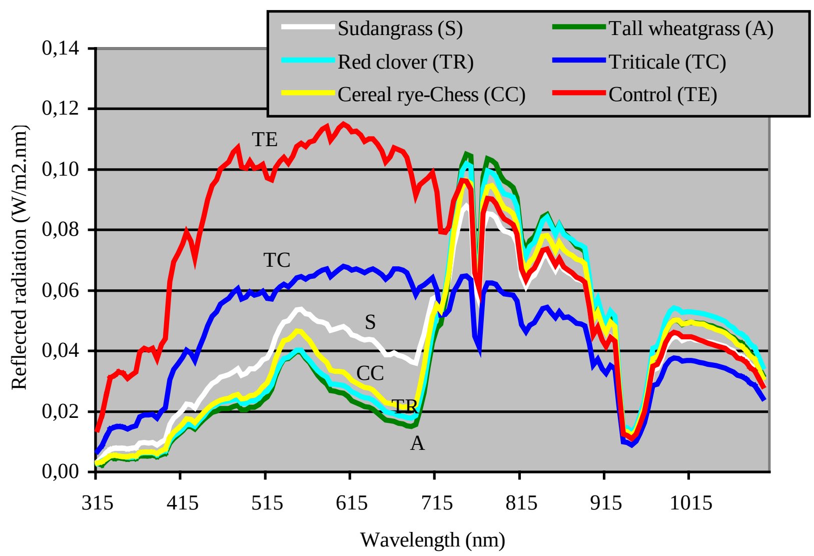

Figure 5. Spectral distribution of reflected radiation. Measurement realized the 01/03/04 between 11 and 13 hs.

Table 3. "Red/Far red" ratio of reflected radiation, 01/03/04. Same letters indicate that there are not significant differences between means (p=0,05 by LSD test).

	Sudangrass (S)	Tall wheat-grass (A)	Red clover (TR)	Triticale (TC)	Cereal rye-Chess (CC)	Control (TE)	Direct radiation
Ratio of R/FR (660/730 nm)	0,58 b	0,26 c	0,29 c	1,21 a	0,34 c	1,28 a	1,31

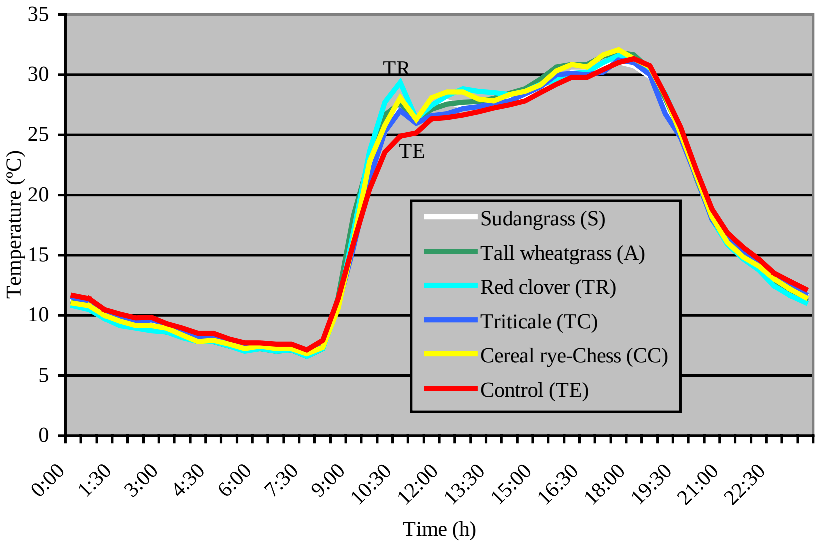

Figure 6. Daily evolution of temperature at bunches level. Mean values of four days during maturation (2 to 5, 8 and 9/03/2004).

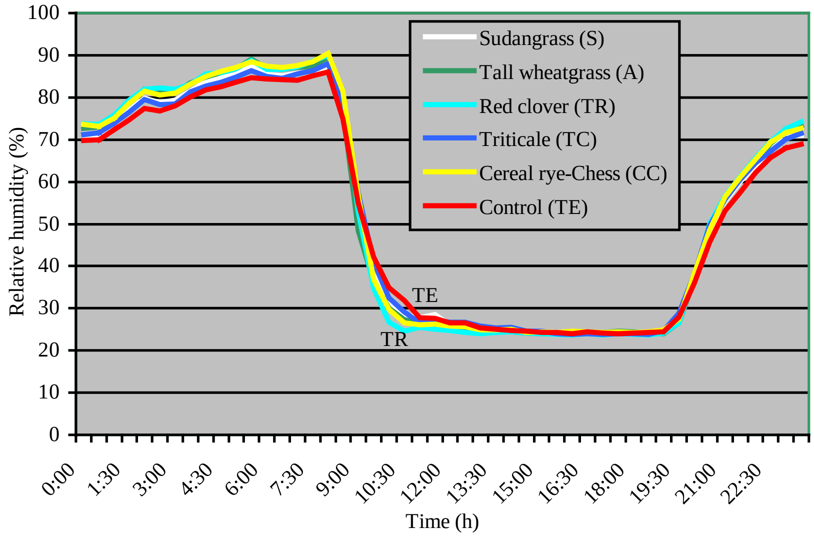

Figure 7. Daily evolution of relative humidity at bunches level. Mean values of four days during maturation (2 to 5, 8 and 9/03/2004).

Table 4. Soil temperature at 15 cm. depth. Mean values of four days during maturation (18 to 20 and 23 to 25/02/04). Same letters indicate that there are not significant differences between means (p=0,05 by LSD test).

	Soil temperature (ºC)		
	Minimum	**Maximum**	**Amplitude**
Sudangrass (S)	20,76 a	25,27 a	4,52 bc
Tall wheatgrass (A)	20,76 a	25,18 a	4,42 bc
Red clover (TR)	20,19 a	24,02 a	3,83 c
Triticale (TC)	20,76 a	25,95 a	5,19 ab
Cereal rye-Chess (CC)	20,57 a	25,08 a	4,51 bc
Control (TE)	20,38 a	26,25 a	5,88 a

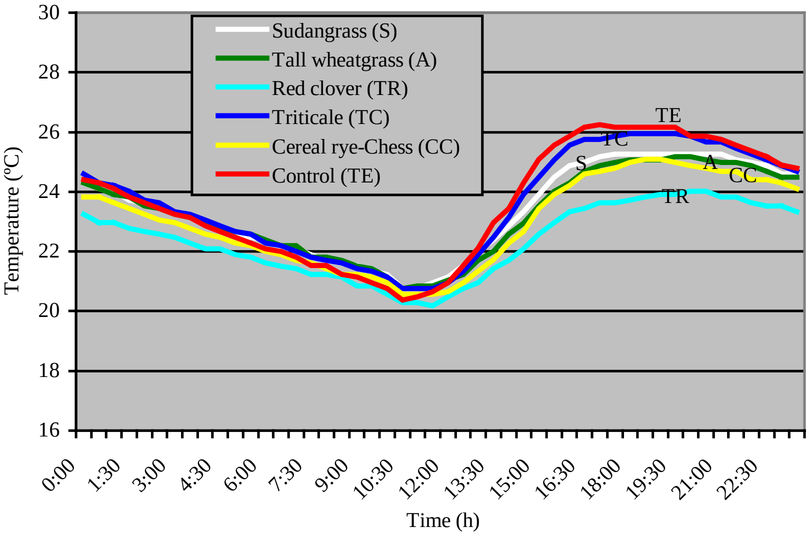

Figure 8. Daily evolution of soil temperature (depth: 15 cm). Mean values of four days during maturation (18 to 20 and 23 to 25/02/04).